Free-Silica in a Non-Chondritic Micrometeorite from Antarctic Ice. M. J. Genge, M. M. Grady and R. Hutchison, Mineralogy Department, The Natural History Museum, Cromwell Road, London SW7 5BD, Great Britain.

Introduction

Of the unmelted micrometeorites 50-100 µm in size recovered from Antarctic ice, almost half have compositions that diverge significantly from bulk CI. These "non-chondritic" Antarctic micrometeorites (AMMs) are coarse-grained (grain-sizes within an order of magnitude of particle size) and consist primarily of anhydrous silicates [1]. Most non-chondritic micrometeorites have textures that suggest they formed by the crystallisation of a melt and might therefore be expected to be fragments of magmatic objects found in meteorites, such as chondrules and igneous clasts. Due to their large relative grain-sizes, non-chondritic particles are unlikely to contain mineral assemblages representative of their bulk parent materials, hence comparisons with meteorites must be based on mineral compositions. Olivine and pyroxene are the most abundant silicates in non-chondritic AMMs, but their compositions are not generally diagnostic of particular meteorite groups [2]. Only unusual non-chondritic AMMs containing phases rare in meteorites or those with restricted mineralogical associations might be interpretable individually. We report the discovery of an unusual non-chondritic AMM (particle CP91-50-096) which contains free-silica and discuss possible genetic relations to silica-bearing objects in meteorites.

Results

Particle CP91-50-096 is 56×70 µm in size and has an irregular partially faceted appearance. Individual faces are rounded. The external surface of the particle is decorated with micron-sized magnetite/maghemite octahedra in a glassy mesostasis. The interior of CP91-50-096 is dominated by zoned low-Ca pyroxenes (Fs_{2-10}, Wo_{2-7}) which occur both as aggregates of laths and as larger anhedral crystals. Small (<4 µm) endiopsides (Fs_2 Wo_{32}) are found adjacent to some low-Ca pyroxenes. Kamacite grains (~5.5 wt% Ni) up to ~5 µm in size are dispersed throughout the particle, the larger of which are subhedral. Mesostasis in CP91-50-096 occurs as isolated irregular areas and is dominated by free-silica (~99 wt% SiO_2), although small areas of aluminosilicate glass are also present. The outer margin of the particle exhibits a continuous vesicular rim consisting of ferromagnesian silicate glass and sub-micron Fe-rich grains which are probably magnetite. This rim is suggested to have formed as a result of heating during atmospheric entry. The rim and the irregular shape of this particle suggest that it escaped bulk melting during deceleration in the atmosphere.

Comparisons with meteorites.

Free-silica occurs as a common accessory phase in enstatite chondrites, aubrites and eucrites [3] and it has also been reported in chondrules and clasts in ordinary [4], CM [5] and K (Kakangari) chondrites [6]. The occurrence of free-silica in particle CP91-50-096 is broadly similar to that in chondritic meteorites in which it is commonly associated with low-Ca pyroxenes. Pyroxene compositions allow the origins of CP91-50-096 to be more closely identified. Low-Ca enstatites in CP91-50-096 are most like those from chondrules in Kakangari [7], and differ from those in E chondrites in that none of the three distinct genetic populations in the latter have an equivalent compositional range to the zoned low-Ca pyroxenes in CP91-50-096 [8]. Low-Ca pyroxenes in free silica-bearing chondrules and clasts from ordinary chondrites (OCs) are FeO-enriched in comparison to CP91-50-096 and have slightly lower wollastonite contents: only enstatite-rich cores of low-Ca pyroxenes in unequilibrated OCs have equivalent ferrosilite contents [4, 9]. CM chondrite low-Ca pyroxenes from rare silica-bearing chondrules reported by Olsen [5] vary considerably in composition; enstatites have lower wollastonite contents (<Wo_2) than observed in CP91-50-096.

High-Ca pyroxenes occur in association with free-silica in O, CM and K chondrites but are unknown in E chondrites. Endiopside is common in K chondrites [7] and was found in a CM silica-bearing chondrule [5]. High-Ca pyroxenes in OC clasts and chondrules are predominantly augite and diopside [4], although rare endiopside can occur in clasts from unequilibrated OCs [9].

The occurrence of free-silica as an interstitial phase in CP91-50-096 suggests that it was precipitated from a melt. Silica phases in the majority of silica-bearing OC clasts and chondrules and CM chondrules occur either as phenocrysts or within mesostasis and are therefore possibly also magmatic in origin. This differs from free-silica in E chondrites and some OC chondrules which occurs as inclusions within low-Ca pyroxene and is suggested to originate by either reduction of FeO-rich pyroxene [8] or by phase separation [10]. Although free-silica is described as common in pyroxene-dominated chondrules in Kakangari [6], its textural relations have not been reported.

Metal in particle CP91-50-096 has ~5.5 wt% Ni and lithophile element contents <0.5 wt% and is, therefore, distinct from that in E chondrites. The Ni contents in metal are in the range of O, CM and K chondrite metal and provide little further discrimination.

Particle CP91-50-096 has therefore general characteristics common to the majority of silica-bearing magmatic objects within chondritic meteorites. A genetic relation to achondrites can be discounted since grain-sizes are small compared to aubrites and eucrites are dominated by pigeonite and augite rather than enstatite. Pyroxene and metal compositions also preclude a genetic relation to E chondrites and the restricted FeO contents of low- and high-Ca pyroxenes suggest that OC materials are also not appropriate parent materials. Silica-bearing objects in CM and K chondrites are therefore the closest analogues to particle CP91-50-096 of which, based on the range of pyroxene compositions and the rarity of free-silica in CMs, a K chondrite source is favored.

Implications

Micrometeorites represent that fraction of the cosmic dust flux recovered from the Earth's surface and are expected to provide a more representative sample of solar system parent bodies than meteorites. Most unmelted fine-grained AMMs have affinities to CM chondrite matrix [1] and therefore broadly support spectral data from asteroids which suggest that CM-like materials dominate the asteroid belt. Fine-grained AMMs, however, comprise only ~50% of unmelted particles in the 50-100 µm size range: the remainder are "non-chondritic". Many of these particles might be expected to be derived from chondrules and clasts in CM chondrites. Particle CP91-50-096 has a texture which suggests a magmatic origin and has mineral compositions which are reminiscent of silica-bearing chondrules in both CM and K chondrites. The interpretation that CP91-50-096 is most similar to K chondrites is at odds with the expectation that CM chondrite materials should also dominate the non-chondritic coarse-grained AMM fraction. However, the reported occurrence of AMMs with affinities to CR chondrites [1] illustrates that particles from rare meteorite groups are represented in the AMM collections.

References

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